TRANSLATION

THERE WILL BE NO PHOTON ROCKET

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THERE WILL BE NO PHOTON ROCKET

V. Smilga

The idea of interstellar ships - those hypothetical subjugators of space - has enjoyed sensational success. This success is expressively reflected in science-fiction creations whose authors have, without restraint, filled the galaxy with every kind of "subrelativistic" and "relativistic" starflyers.

This "star sickness" is of course understandable. The idea of conquering the unfathomable reaches of space is in itself extremely attractive. And it is especially alluring today when the earth's gravity has been overcome, artificial satellites of the earth and sun have been created, and photographs have been taken of the moon.

Unfortunately, this dream, despite how beautiful it is, is no more than a dream. As yet there is not the slightest real basis for thinking that mankind can create rockets capable of linking us with other stellar worlds.

To me personally this conclusion is very unpleasant. It would be very nice to know a way of reaching the distant stars. Unfortunately however, all of the talk about photon rockets cannot be rated as more than very attractive but nevertheless a very baseless fiction.

I shall endeavor to objectively state all the "ayes" and "nays" and the reader may decide whether a judgment so categorical and so little-comforting is fair.

The star closest to the sun (Proxima Centauri) is 4.2 light years distance from us. To reach this star a rocket must attain velocities at least comparable to the speed of light. Otherwise an expedition would last for tens of thousands of years. For example, at a velocity of 100 kilometers per second, which is very respectable for an interplanatary "cruise", it would take about 12,600 years to reach the constellation Centaur.

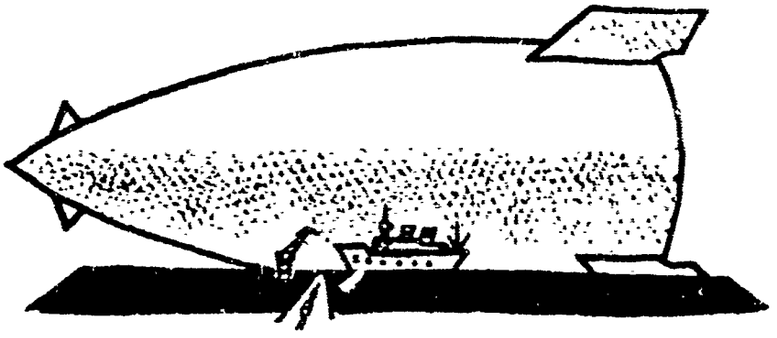
At a velocity of 100,000 kilometers per second the entire flight would take 28-30 years, a considerable but acceptable time. And in order to shorten the period of interstellar travel to such limits, the photon rocket was called upon.

"SUBRELATIVISTIC" ROCKETS - A GROUNDLESS BUT RELATIVELY POSSIBLE FANTASY

First of all let us endeavor to evaluate the useful mass of such a rocket, in other words, all of its mass with the exception of fuel. Actually, there is rich material here for a flight of the imagination but let us say that one hundred thousand tons is the minimum value which may be taken (for even in fantasy it is necessary to preserve conscience!).

At first glance the figure is colossal. It is worth remembering, however, that the displacement of the largest ocean vessels reaches 50-80 thousand tons. The dimensions of the starflyer can scarcely be conceived smaller simply because, as we have already concluded, a colossal store of fuel is needed and must be kept somewhere. The body also must be immeasurably stronger than that of a battleship for,

you see, the heaviest artillery fire is like childs play compared with the continuous bombardment by meteorites and interstellar gas which awaits the rocket in its path.



In attempting to evaluate the mass of the rocket it is possible, of course, to neglect equipment, scientific apparatus, and all of the complex devices for flight control, but the rocket engine may not be dropped. Unusually powerful and based, certainly, on atomic energy and consequently enclosed in an exceptionally heavy shield, the engine alone must weigh at least ten thousand tons.

In brief, the most avid enthusiast must agree that if we estimate the total mass of the rocket at 100 thousand tons we have already underestimated it by a factor of ten. And if we later verify this figure it will only be because the baseslessness of the idea of interstellar flight has become very clear.

Let us make a concession to the dreamers and, having manifested the well-known playfulness of thought, imagine that the body of our ship successfully withstands collision with cosmic dust and shields out cosmic radiation. Generally speading, no ultrabody is of any help at such velocities but let us assume that we have coped with this problem.

The fact is that so much thought has been given to the engine that there has been little interest in other undesirable aspects.

Problem number one - fuel.

If we are going to talk about the photon rocket then any kind of chemical fuel must be rejected at once and irrevocably. Actually, at a speed of 100,000 kilometers per second every kilogram of rocket mass possesses $5.4 \cdot 10^{22}$ ergs of energy. It is necessary to "pay" for this energy. Assuming also that the coefficient of useful action of the engine equals unity, neglecting the retarding effect of gravity and the resistance of the medium, we arrive at the following conclusion: in order to accelerate one kilogram of mass, $2.4 \cdot 10^{23}$ ergs of energy are required.

These calculations of course are barbarously crude. Indeed, the fuel is located on board the rocket and thus "ballast" is burned. But for the sake of calarity we shall content ourselves with the established, very much reduced, value of energy discharge.

The volume of ordinary fuels necessary for obtaining this energy discharge is calculated in tens, hundreds, and thousands of cubic kilometers. An inconceivable amount! Therefore, the energy source might be a nuclear reactor - nuclear fuel.

At first glance atomic energy saves the situation. Actually, for every kilogram of discharged mass, it is necessary to "burn" only 60 grams of any substance if all of this mass is converted to electromagnetic radiation.

The processes which convert the entire reacting substance into energy are well known. This reaction is the annihilation of elementary particles by corresponding antiparticles.

However, possessing even the most active imagination, it must be recognized that there is not the slightest hope of using such reactions for rockets since it is impossible to imagine a reservoir for

antiparticles. Having touched the walls they instantaneously explode with incredible force after which the rocketship and crew are dispatched straightway to the "upper world". There is no value in going over all the other arguments against the reality of an "antifuel" since they are very numerous and since we are flying "only" to the constellation Centaur it is possible to manage without antimatter, having reconciled ourselves with typical fuel. It is possible to calculate either on the basis of the already mastered disintegration of heavy nuclei or of the thermal-nuclear reactions for synthesizing light nuclei, the energy base of the near future. In this case, in order to disperse one kilogram of mass at a velocity of 100,000 kilometers per second only a few, possibly ten, kilograms of fuel are required.

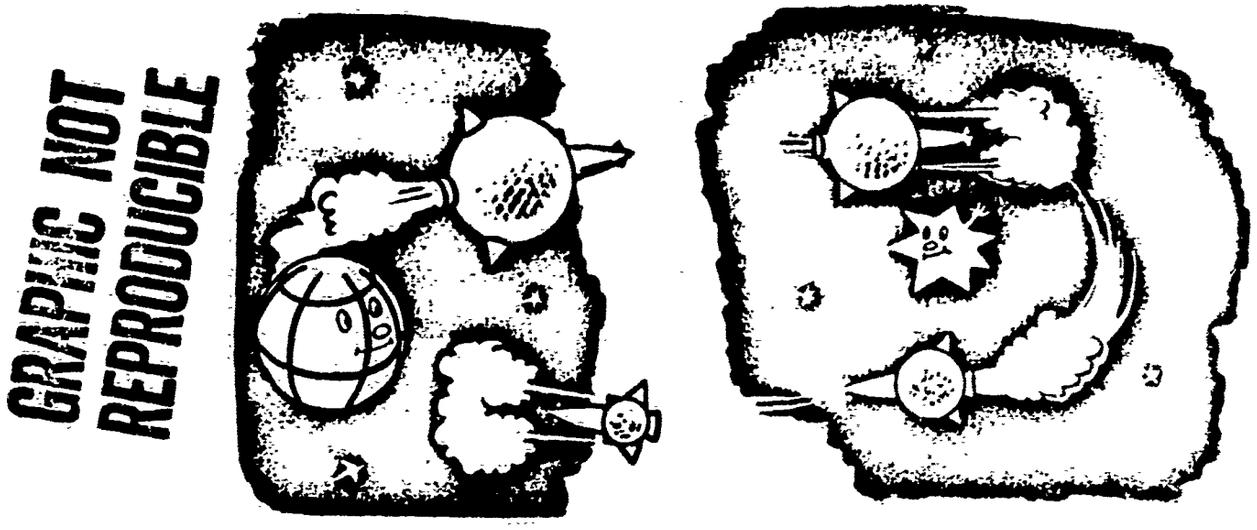
Incidentally, this atomic fuel is also not very realistic. The energy it must liberate is fantastically great; immeasurably greater than is liberated during nuclear reactions known at this time.

Remembering that in the process of traveling the ship must gather up speed at least two times (when lifting-off from the earth and when taking up the return path to the earth) and must cancel it two times (when approaching the star and the earth), we conclude that for every kilogram of rocket payload it is necessary to take, as a minimum, 10 tons of nuclear fuel. This is demonstrated by simple calculation which need not be presented here.

Thus, if the payload is 100 thousand tons, the initial mass of the rocket grows to a minimum of one billion tons!

Let us now attempt to ponder how powerful the engine of this interstellar gaint must be. Simple calculation says: for a rocket with a mass of a billion tons even an acceleration of $1 m/sec^2$, which

is tiny for interstellar flight, the energy of the thrust stream ejected per second amounts to a hardly comprehensible value of 10^{26}-10^{27} ergs.



It is somewhat difficult to explain these figures in earthly terms. The total energy obtained by the earth from the sun each second is about 550 times less. In order to develop 10^{27} ergs it is necessary to completely "cremate" 1100 kilograms of mass each second. In other words, this energy may be obtained by exploding about a million atomic bombs!

This energy is so improbably vast that it is possible to permit oneself a broad merchant's gesture and reduced it by one hundred, one thousand, if you wish, ten thousand times. It is equally impossible to produce a rocket engine with a power of 10^{27} erg/sec or with a power of 10^{23} erg/sec. In both cases the generated energy would instantly reduce the interstellar ship to ashes. Here we must keep in view the fact that all the time we have been going in the direction of improving the conditions of flight, the values of rocket mass and acceleration were assiduously underestimated.

And nevertheless, "subrelativistic" rockets are nothing more than poor relatives to "true relativistic" rockets - the subjugators of the cosmos.

FLIGHT TO THE DEPTH OF THE GALAXY - FANTASY BEYOND THE LIMT OF "GOOD AND EVIL"

Usually when someone writes about photon starflyers he by no means has in mind such "modest" rockets as we have mentioned above. No! He has in mind interstellar craft with velocities approaching that of light.

The dimensions of our galaxy are on the order of hundreds of thousands of light years. The period of each expedition is naturally limited by the duration of human life. It would seem that with any conceivable and inconceivable technological accomplishments, man is doomed to remain within an insignificant island within several tens of light years. But it is assumed that, proceeding from Einstein's theory, the passage of time on a rocket at velocities close to the speed of light makes it possible, at least in theory, to reach the farthest corners of the universe. Thus it seems that the rocket succeeds in gathering the necessary speed in about 10 of its own years. With an acceleration of $10 m/sec^2$ it is possible to attain the velocity needed to fly around the galaxy within the period of a human lifetime. Thus it is that from this aspect everything is more or less in order.

Actually, having returned to the earth, where during the period of the journey hundreds and thousands of years have passed, the travelers will find an altogether new humanity. But the grandeur of the problem, undoubtedly, is requited by the "sacrifices" associated with a flight into "eternity".

It is "simply" a matter of attaining a velocity approaching, as

a maximum, the speed of light.

As the speed of light is approached, the mass approaches infinity and a continuously increasing expendure of fuel is required in order to accelerate the rocket. Fuel will be burned many thousands of times faster than in "modest" subrelativistic rockets.

But let us assume that some remarkable means has made it possible to produce an engine which safely developes the monstrous energies required to accelerate the ship at velocities approaching that of light.

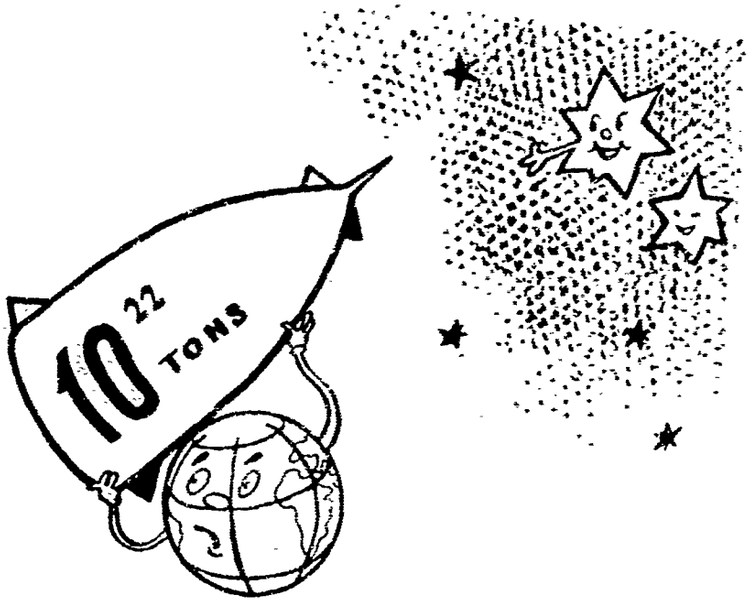
Let us further assume that an amazing nuclear superfuel has been obtained with an energy release of unity (the total reacting mass converted to radiation).

It then turns out that in order to bring the rocket to a velocity of 0.9999 that of light (at such a velocity the radius of action of the rocket is limited by a reasonable period of travel - only hundreds of light years total) requires about 140 kilograms of fuel for each kilogram of rocket payload. Taking into account the fact that in each journey there are a minimum of two accelerations and two decelerations, we find that the mass of fuel exceeds the payload by a factor of four hundred million.

It may be noted, just for the interest, that ata velocity necessary for flying around the galaxy in a reasonable period, the fuel mass would be approximately 10^{17} times greater than the rocket payload. Taking, as before, the useful mass at one hundred thousand tons, "a laughably small value of course", we obtain a total mass of 10^{22} tons. For comparison - the mass of the earth is $6 \cdot 10^{21}$ tons.

Only a couple of words suffice for the idea of the "flying tube", as the through-feed photon rocket is called. It is thought that

interstellar substance dragged in from the cosmos may be used as the fuel thus permitting a reduction in the initial fuel supply. We are distracted from all of the difficulties. We agree that interstellar substances can be turned into an ideal fuel. Nevertheless, such an engine does not essentially save the position. At "low" velocities (to 200 thousand kilometers per second) too little substance (fuel) reaches the rocket. But during sub-light flights the effectiveness of the feed-through engine becomes insignificant: the difference between the velocities of particles drawn in and ejected will be too small.



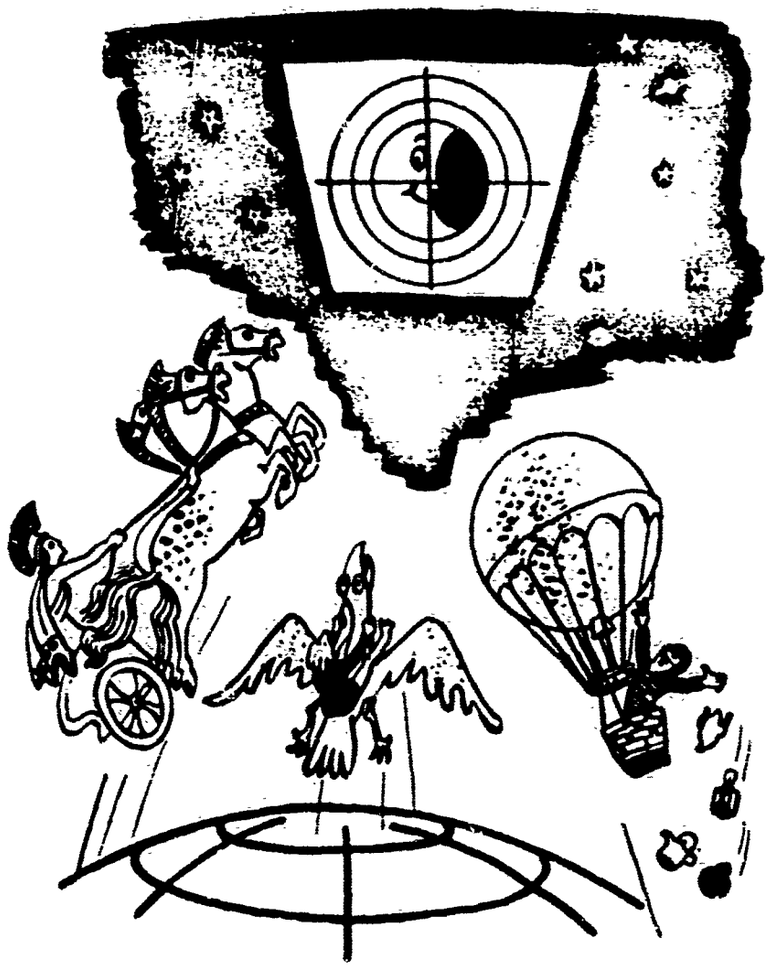
DREAMS AND POSSIBILITIES

Perhaps it can be said that the idea of the photon rocket is evidence of a certain limited quality in human imaginativeness. Usually, even in fantasies, the most trodden and most erroneous path, the monstrous exaggeration of known means, is followed.

The Greeks endowed the Gods with remarkable horses and chariots, not suspecting the startling force of steam. And in the century of

steam machines people imagined stupendous steam vehicles, not imagining internal combustion engines.

In ancient stories the moon was reached on backs of enormous birds and in the 19th century Edgar Allan Poe sent an air balloon.



In our time, the time of rockets and nuclear energy, photon rockets have naturally and unavoidably "appeared". And, of course, the story repeats itself. If the stars are ever to be reached the journey will be accomplished by some means which is completely inconceivable and improbable to us.

In conclusion permit me to answer a question which may have arisen during the reading of these pages. Is it sensible to attack

the photon rocket so servely? Certainly the dream of flying to the stars is truely wonderful.

The dream is wonderful, but it is necessary to dream sensibly. I have faith that everything written about photon ships was written with the best of motives. But in fact they disorient those who cannot investigate for themselves and must rely on someones word. As a result we read that the flight to the stars is a problem of the next few decades, or encounter a serious discussion of the "problems": at what quantum - high or low frequency - should the engine operate?"

The impression should not be created that the path is essentially clear and that there is practically no time to think about engineering projects. Science needs no publicity.

The stars cannot be reached with nuclear fuels, not with any kind of super-ultra-extra-material, not with any photon rocket. Something unknown is needed. Something as unknown as the atomic power station was to Pithecanthropus.

A naive, unreasonable, childish, but ineraticable faith in this unknown remains with me and, undoubtly, with every man of our century.

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